Paper No. 03-3149

FREEWAY PLANNING METHODOLOGY

Elena Shenk Prassas
Polytechnic University
6 Metrotech Center
Brooklyn, N.Y. 11201
Ph: 718-260-3788
Fax: 718-722-7271
Email: eprassas@poly.edu

Douglas McLeod
Florida Department of Transportation
605 Suwannee St: MS 19
Tallahassee, FL 32399-0450
Ph: 850-414-4932
Fax: 850-921-6361
Email: **douglas.mcLeod@dot.state.fl.us**

Gina Bonyani
Florida Department of Transportation
605 Suwannee St: MS 19
Tallahassee, FL 32399-0450
Ph: 850-414-4707
Fax: 850-921-6361
Email: **gina.bonyani@dot.state.fl.us**

Word Count: 6050
Revised: November 2002

FREEWAY PLANNING METHODOLOGY

Elena Shenk Prassas, Polytechnic University, 6 Metrotech Center, Brooklyn, NY 11201
Douglas McLeod, Florida Department of Transportation, 605 Suwannee St: MS 19, Tallahassee, FL 32399-0450

Gina Bonyani, Florida Department of Transportation, 605 Suwannee St: MS 19 Tallahassee, FL 32399-0450

ABSTRACT

A major new chapter of the HCM2000 is on freeway facilities. It is a detailed operational methodology that combines analyses of basic freeway segments, weaving areas, off-ramp areas and on-ramp areas. However, the new chapter does not contain guidance or examples for planning or preliminary engineering applications. In order to meet its numerous needs, the Florida Department of Transportation (FDOT) wanted to develop a freeway facility application that extends the HCM for generalized planning and preliminary engineering purposes while not being inconsistent with the HCM2000.

Such a methodology was developed, documented, made into an executable software called FREEPLAN, and is now being implemented throughout the State. The methodology is firmly based upon HCM detailed analysis procedures, but has assumptions and defaults that allow planners and engineers to use it effectively. At a generalized planning level, the basic construct was to provide tables of design volumes "v" and AADT's that could be achieved for various levels of service and freeway configurations, for the default parameter values. At a preliminary engineering level, specific freeway facility inputs are used to determine v/c, average travel speed, average density, and level of service grades. The initial results of applying the Florida freeway planning methodology to actual Florida data were outstanding in both urbanized and rural areas.

INTRODUCTION

Florida's Quality/Level of Service (LOS) Handbook [1] and its accompanying software are widely used throughout Florida and much of the U.S. by engineers, planners and decision makers for planning and preliminary engineering applications based on the Highway Capacity Manual (HCM). In the late 1980's the Florida Department of Transportation (FDOT) began developing planning applications of the HCM methodology because of the numerous highway capacity and quality of service applications in the state and the desire to use professionally accepted techniques.

Although there are a few extensions to the HCM procedures based on statewide research and specific application needs, Florida's Quality/LOS Handbook and software are essentially replications of point, segment and facility analyses of the HCM at a planning level. Historically, FDOT has updated the Handbook and software to incorporate the latest HCM updates soon after their release. For motorized vehicle analyses, the Handbook is now based on the 2000 edition of the HCM (HCM2000) [2].

A major new chapter of the HCM2000 is on freeway facilities. It is a detailed operational methodology that combines analyses of basic freeway segments, weaving areas, off-ramp areas and on-ramp areas. However, the new chapter does not contain guidance or examples for planning applications.

Most existing planning applications make use of the basic freeway segments chapter of the HCM and therefore do not account for the effects of interchanges. In fact, the basic freeway segment chapter is applicable to only those freeway segments outside the influence area of interchanges. In essence applying the basic freeway segment analyses to urban freeways with interchanges less than 1 mile apart is inappropriate because basic segments do not exist under those circumstances. Therefore, to meet its numerous planning needs, FDOT wanted to develop a freeway facility application that extends the HCM for planning and preliminary engineering purposes while not being inconsistent with the HCM2000.

LEVELS OF ANALYSIS

Highway capacity and quality of service can be viewed to exist at three planning levels: operational, conceptual, and generalized.

Florida relies on the HCM or TSIS/CORSIM [3,4,5] for interchange justification reports and other detailed operational techniques to evaluate freeways. The new HCM2000 freeway facility chapter and simulation packages meet those needs.

Conceptual planning (preliminary engineering) is applicable when there is a desire for a good estimate of a facility's LOS without doing detailed, comprehensive operational analyses. Examples of conceptual planning are:

- trying to reach a decision on design concept and scope for a facility (e.g., a four-lane tolled freeway with average interchange spacing of every other mile), or
- conducting alternatives analyses (e.g., a four lane freeway versus a six-lane expressway), and determining needs when a generalized planning analysis is simply not accurate enough.

Generalized planning is applicable for broad applications such as statewide analyses, initial problem identification, and future year analyses. Generalized planning is applicable when the desire is for a quick, "in the ball park" estimate of LOS, and makes extensive use of default values. Service volume tables are generally used for these estimates of LOS, employing Florida's Generalized Level of Service Volume Tables. These are presently the most frequently used service volume tables in the United States.

ACCURACY AND CONSISTENCY

Although *accuracy* is of course desired, at a generalized planning level, *consistency* in freeway values across freeway groupings is frequently more important. These statewide tables become the initial LOS tool from which FDOT determines freeway improvement priorities in its Florida Intrastate Highway System Decision Support System [6].

These tables also become fundamental building blocks for capacity and traffic assignment for all urban area travel demand forecasting models in the state. Because of statewide acceptance and consistency in application, the tables serve as a primary tool for reporting to the state legislature and others the quality of service provided by the state's freeways and how trends change over time [7].

Furthermore, in the growth management arena, they usually serve as the initial screening tool for the impacts of many major developments. Annually, hundreds of millions of dollars of investment allocations are initially dependent on these generalized planning analysis tools.

Conceptual planning, unlike generalized planning, evaluates an individual facility. For these types of analyses, the accuracy is more important than numerical consistency among freeways. In such cases, 1) specific traffic and roadway values for K, D, PHF, HV, driver characteristics, lane usage and operating speeds are desired; 2) specific geometrics such as spacing between interchanges, gore to gore lengths, and freeway configurations are also desired.

Conceptual planning analyses are often sufficient for initial project screening. They are also useful to analysts who desire more detailed analyses without having to complete a full operational analysis.

In summary, Florida has a history of tying its capacity and quality of service analyses to the HCM. However, in its current form the HCM2000 freeway facility chapter does not meet the needs for generalized and conceptual planning. FDOT desired an application to address those planning and preliminary engineering needs and have it directly tied to the HCM.

DEVELOPMENT OF THE PLANNING METHODOLOGY

In the above context, it was essential to develop a freeway facility methodology and to provide planners and engineers with an effective support tool, which would allow them to make use of the methodology. The concept is straightforward, in that freeway performance is assessed in terms of the average travel speed and density of the through vehicles.

Step 1. Define Facility

A freeway facility may be considered as a sequence of basic segments, interchanges, and toll plazas. An “interchange” may be a single ramp, but is almost always a pair of ramps as well as an overpass/ underpass area. In the present usage, it includes the upstream and downstream influence areas extending 1500 feet from the off-ramp and on-ramp gores. Interchange elements are illustrated in Figure 1.

No precise guidance is given on the proper length of termini of freeway facilities. FDOT’s suggested guidance is as follows:

- Length
  - At least 3 miles in downtown areas
  - At least 5 miles in other parts of urbanized areas
  - At least 10 miles in rural areas

- Termini
  - Intersecting freeways and selected intersecting principal arterials
  - Changes in the number of through lanes

Step 2. Assign Freeway Class

For planning purposes, several assumptions as extensions to the HCM2000 were made. Freeway classification is not currently in the HCM2000, but is useful for planning purposes to determine the defaults to be used.

The freeway is classified as one of 4 classes (1, 2, 3, or 4) depending on the typical interchange spacing, posted speed limit, and area type of the freeway. Table 1 shows the classes and their characteristics. The interchange spacings and area types are based on Florida's Access Management Classification System and Standards [8].

Step 3. Divide freeway into segments

The freeway is divided into three possible segment types:

1. Basic Segment,
2. Interchange, or
3. Toll Plaza

Interchanges are then categorized by design type: as diamond, partial cloverleaf, full cloverleaf, or unknown design.

Conceptually, interchanges are separated into three "subsegments:"

1. Off-ramp influence area,
2. Overpass/Underpass area analyzed as a basic segment, and
3. On-ramp influence area.

Another assumption, not currently in the HCM but based on data from Florida [9], is that capacity reductions occur in interchange areas. The following passenger car per hour per lane capacity reductions occur for the two outside lanes of freeways within interchange influence areas:

1. 200 vph for the off-ramp influence area,
2. 50 vph for the overpass/underpass areas, and
3. 100 vph for the on-ramp influence area.

Auxiliary lanes are additional lanes on freeways that connect on ramps and off ramps of adjacent interchanges. FDOT's methodology addresses these auxiliary lanes based on three approximate distances. If the length of the auxiliary lane is less than 2500 feet, they are analyzed using the weaving analysis procedures found in the HCM2000. If the lanes are greater than 3000 feet in length, they are considered as full lanes for capacity purposes. If the auxiliary lanes are between 2500 and 3000 feet in length, they are considered as adding an extra half lane of capacity.

Step 4. Compute LOS

An important planning assumption of the Florida approach is that free-flow speed is 5 mph greater than the posted speed. This 5-mph differential is based on research by FHWA on U.S. streets and highways [10]. Because posted speeds are readily available, this reasonable surrogate simplifies analyses greatly. Nevertheless, FDOT's methodology allows the use of actual free-flow speeds if the analyst chooses to do so.

The basic and well-accepted relation v = (K) (D) (AADT) is used to link demand volume "v" with the AADT, by the directional factor "D" and the k-factor "K" to determine the freeway input volume entering the first freeway segment.

The task then becomes to solve for density and speed using the procedures of the HCM2000 for the appropriate segments of the freeway.

The basic segments are analyzed with the procedures from Chapter 23, "Basic Freeway Segments".

Interchanges must use a combination of procedures. All interchanges, except the full cloverleaf, can be divided into the off-ramp influence area, the overpass/underpass area, and the on-ramp influence area, as shown in Figure 1. Individual ramps are analyzed using the procedures from Chapter 25 "Ramps and Ramp Junctions" to analyze the 1500 feet upstream of the off ramp and 1500 feet downstream of the on ramp.

Figure 2 shows a full cloverleaf interchange. For the full cloverleaf design, there are four ramps to be analyzed and three basic segments. If there is an auxiliary lane between the two middle ramps then the procedures from Chapter 24 "Freeway Weaving" must be used.

Since for planning purposes, specific details are not required about each ramp, a weighted average is calculated to give the user an overall density and speed for the interchange as a whole, and a level of service is assigned based on this weighted density. The formula for interchange density is:

$$ID = d_{off} * (\frac{1500}{5280}) * l_{off} + d_b * (\frac{len_b}{5280}) * l_b + d_{on} * (\frac{1500}{5280}) * l_{on},$$

where: ID = Interchange Density,
d_{off} = density of off-ramp influence area,
l_{off} = number of lanes in off-ramp influence area,
d_b = density of basic segment between ramps,
l_b = number of lanes between ramps,
len_b = length between ramps,
d_{on} = density of on-ramp influence area,
l_{on} = number of lanes in on-ramp influence area.

The LOS breakpoints for an interchange use the definitions from the basic freeway segments chapter as shown in Table 2.

Overall facility measures of effectiveness are also determined. Weighted averages are used to find facility-wide v/c, speed and density (with LOS based on density).

Step 5. Compute Service Volume Tables

In addition to the determination of LOS for roadways, the other primary planning or preliminary engineering application is to determine maximum service volume for a given LOS. Service volume tables are the primary tool for this latter application. Given a set of specified input values, the task then becomes to solve for the demand volumes “v” at which each LOS threshold is attained.

Specifically, the maximum service flow rate based on the free-flow speed is used for the freeway. One must then search for the segment (usually an off-ramp influence area) with the lowest capacity. The volume associated with a v/c of 1.0 for the peak 15-minute period at the worst segment is the maximum service volume for LOS E. For other LOS service volumes, the LOS E volume is multiplied by the maximum v/c criterion (shown in Table 3) for the applicable LOS grade [11].

Table 4 shows a basic rendering of the service volume tables for a set of input values. This table is in a form comprehensible to most planners: for a reasonable set of input values, the maximum AADT that can exist *while attaining the indicated LOS* is clearly indicated. If a given project has a significant impact on this LOS, due to AADT added, then more detailed analysis is typically required.

A special important application of service volume tables is the development of a set of “generalized maximum service volume tables” for use on a regional statewide or national basis. Such generalized service volume tables make extensive use of defaults. Florida’s generalized service volume tables are probably the most recognized in the U.S. and are probably the most thoroughly researched for determining applicable statewide default data.

DEFAULT VALUES

For Florida’s generalized service volume tables, statewide defaults were determined for the analysis hour factor (K), directional distribution factor (D), peak hour factor (PHF), percent heavy vehicles (HV), and local adjustment (driver population) factor [12]. After extensive review of the data, FDOT divided its permanent count station data by area type in which freeways are located and filtered out many counts because they were more reflective of measured volumes than demand volumes.

Table 5 shows Florida's defaults for geometry by Class.

K and D values were determined for four periods of analysis frequently used in Florida:

1. the 30th highest traffic hour (K_{30}), typical design hours,
2. the 100th highest traffic hour (K_{100}), typical planning analysis hours,
3. the peak hour of the day ($K_{p/d}$), typical of many preliminary engineering studies,
4. the typical weekday 5-6 pm period ($K_{5\text{-}6}$), frequently used in performance reporting.

Table 6 shows default K factors and typical ranges by Class.

A special one month long heavy vehicle count study was conducted specifically to help generate the state's most recent service volume tables. Table 7 shows the default heavy vehicle factors by class and study period. Local adjustment factors were based on Florida research in 1997 [13] and previous values used by FDOT and are shown in Table 8. The local adjustment factor is important because it affects capacity directly, as it is multiplied by the final calculation of capacity.

THE SOFTWARE IMPLEMENTATION

The default generalized service volume tables printed in the Florida Quality/LOS Handbook are known to be too static, and are useful only for the broadest applications. Users have justification to use other values and parameters, and need convenient tools for the purpose of analyzing facilities at a more detailed level. Therefore, companion executable programs were provided as an integral feature of the Handbook. The tool created to implement the described methodology is called FREEPLAN (freeway planning).

In designing the appropriate tool, the dominant considerations were: (1) the tool must be easily used by planners and engineers with varied levels of proficiency and computer literacy, (2) the tool must be straight-forward and the implementation must not require additional software purchases. It was decided to create the programs for the 2000 FDOT handbook in Visual Basic for Windows.

FREEPLAN is an executable program in which key parameters are specified for the facility as a whole and then for individual segments. Default values are built into the program for ease of use by planners.

COMPATABILITY WITH FLORIDA FIELD COUNTS

The initial results of applying the Florida freeway planning methodology to actual Florida data were outstanding in both urbanized and rural areas. Based on a limited sampling of sites, the capacity that can reasonably be expected on Florida's six-lane freeways in urbanized areas appears to be approximately 2030 vehicles per hour per lane (vphpl) [9]. Applying the freeway planning methodology and statewide defaults resulted in a volume of 2050 vphpl.

May [14] recently reported that the capacities of basic and ramp segments appearing in the HCM2000 are 4 to10 percent higher than those analyzed in the field. Preliminary results in Florida confirm that finding. Furthermore, volumes in the inside (left-most) lane are approximately 40% and 20% higher, respectively, than the outside (right-most) and middle lanes. It is believed that applying the capacity reductions for the two outside lanes in the off ramp influence area is the key to obtaining realistic field results from the HCM2000 methodology. Noteworthy, applying the 200 pcphpl reduction in capacity at freeway off ramp influence areas is nearly equivalent to the 4 to 10 percent reduction reported by May for freeways ranging from 10 to 4 lanes.

Based on limited observations, the capacity of Florida's rural freeways appears to be approximately 1750 vphpl [15]. Historically, FDOT has used the equivalent of a driver population factor of 0.90 in rural areas when developing its generalized service volume tables. That value is consistent with independent Florida research [12]. By applying the 0.90 driver population factor, other statewide defaults, and the capacity reductions at the off-ramp influence areas, the resultant capacity value for Florida's rural freeways is approximately 1800 vphpl. Thus, again the freeway planning methodology matched very well with Florida field data.

SUMMARY

This paper reports the development of a freeway planning methodology, its implementation and application in the State of Florida. The methodology is now in the early stages of statewide implementation. The initial results of applying the Florida freeway planning methodology to actual Florida data were outstanding in both urbanized and rural areas.

REFERENCES

[1] Florida Department of Transportation, *Quality/Level of Service Handbook*, Tallahassee, FL., 2002.

[2] Transportation Research Board, *Highway Capacity Manual*, Washington, D.C., 2000.

[3] Lieu, Henry C. “CORSIM: A state-of-the-Best Practice for Traffic Operation”, Research and Technology Transporter, FHWA, 1998.

[4] Daigle, G, Krueger, GD, Clark, J, “TSIS: Advanced Traffic Software Tools for the User,” Conference on Traffic Congestion and Traffic Safety in the 21st Century: Challenges, Innovation, and Opportunities, ASCE, June 1997.

[5] Halati, A., Lieu, H., Walker,S., “CORSIM: Corridor Traffic Simulation Model”, Conference on Traffic Congestion and Traffic Safety in the 21st Century: Challenges, Innovation, and Opportunities, ASCE, June 1997.

[6] Florida Department of Transportation, Florida Intrastate Highway System Decision Support System, Tallahassee, FL., 1998.

[7] Florida Department of Transportation, Florida’s Mobility Performance Measures Program, Tallahassee, FL., 2001.

[8] Florida Department of Transportation, Rule 14-97.003 Access Management Classification System and Standards. Tallahassee, FL. 1990.

[9] Florida Department of Transportation, Unpublished data on Miami and Tampa Freeways, 1990-2001.

[10] Tignor, Samuel C. and Warren, Davey, “Driver Speed Behavior on U.S. Streets and Highways,” ITE 1990 Compendium of Technical Papers.

[11] Exhibit 23-3, HCM2000, Transportation Research Board, *Highway Capacity Manual*, Washington DC, 2000.

[12] Shaw, T. and McLeod, D. *Final Report*, Florida Study on generalized statewide defaults for K factors, and others, 2001.

[13] University of South Florida for the Florida Department of Transportation, Driver Population Factors in Freeway Capacity, Tampa, Fl., 1997.

[14] May, et al., “Freeway System Research Beyond the HCM2000,” presented at the 2001 TRB Annual Meeting.

[15] Florida Department of Transportation, unpublished data, 1999 – 2001.

LIST OF TABLES.

LIST OF FIGURES

TABLE 1. Class Types for Freeways

Class	Typical Interchange Spacing	Posted Speed Limit	Typical Area
1	≥ 6	70	Rural
2	3 - < 6	65,70	Small Urban/ Transitioning
3	2- < 3	55, 60, 65, 70	Suburban Urbanized
4	<2	55	CBD Urbanized

TABLE 2. LOS Definitions For Freeway Facility

LOS	Density Range
A	[11
B	>11 - 18
C	>18 - 26
D	>26 - 35
E	>35 - 45

TABLE 3. v/c ratio LOS Breakpoints for Service Volume Tables

FFS	>= 75 mph	70 mph	65 mph	60 mph	55 mph
LOS	Maximum v/c ratio				
A	.34	.32	.3	.29	.27
B	.56	.53	.5	.47	.44
C	.76	.74	.71	.68	.64
D	.9	.9	.89	.88	.85
E	1	1	1	1	1

TABLE 4. Service Volume Table for a Class 3 Freeway with 1.5 mile Basic Segments alternating with 1 mile Interchanges and 70 mph Free Flow Speed.

Lanes	A	B	C	D	E
	Peak Hour Volume Peak Direction				
2	1270	2110	2940	3580	3980
3	1970	3260	4550	5530	6150
4	2660	4410	6150	7480	8320
5	3360	5560	7760	9440	10480
6	4050	6710	9360	11390	12650
	Peak Hour Volume Both Directions				
4	2310	3840	5350	6510	7240
6	3580	5930	8270	10050	11180
8	4840	8020	11180	13600	15130
10	6110	10110	14110	17160	19050
12	7360	12200	17020	20710	23000
	AADT				
4	23800	39600	55200	67100	74600
6	36900	61100	85300	103600	115300
8	49900	82700	115300	140200	156000
10	63000	104200	145500	176900	196400
12	75900	125800	175500	213500	237100

TABLE 5. Defaults of Freeway Geometry by Class

Freeway Class	Number of Sections	Type of Section[1]	Length of Section[2]
1	4	Basic/Diamond	6 mile Basic/ 1 mile Diamond
2	4	Basic/Diamond	3 mile Basic/ 1 mile Diamond
3	4	Basic Diamond	1.5 mi Basic/ 1 mi Diamond
4	5	All Diamonds	1 mi

[1]Type of Section is the divisions of the freeway into a Basic, Interchange, or toll section.
[2]Length of Section is the distance in feet of each defined section.

TABLE 6. Default K factors by Class and Study Period

Class	**K30**	**K100**	**Kp/d**	**K5-6**
1	0.125	.104	.073	.057
2	0.113	.100	.073	.062
3	0.109	.097	.081	.074
4	0.109	.097	.081	.074
Class	Typical K factor Ranges			
1	.09-.18	.07 - .12	.06 - .1	.05 - .09
2	.095-.15	.07 - .12	.06 - .1	.05 - .09
3	.08 - .12	.07 - .12	.06 - .09	.05 - .09
4	.08 - .12	.07 - .12	.06 - .09	.05 - .09

TABLE 7. Default Heavy Vehicle Percentages by Class and Study Period

Class	Typical Heavy Vehicle (HV) Percentages			
1	5	9	12	9
2	6	9	11	9
3	6	6	6	6
4	6	4	6	4

TABLE 8. Default Local Adjustment Factors by Class

Class	Local Adjustment (Driver Population) Factor
1	.9
2	.95
3	.98
4	1.00

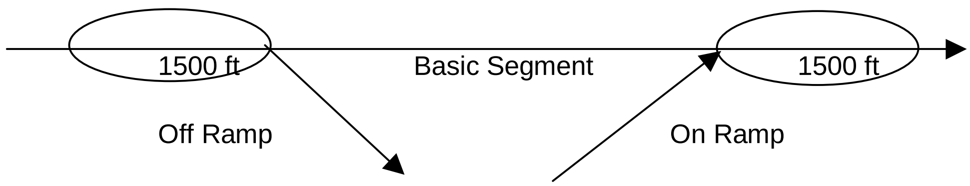

Figure 1. Segments of an Interchange

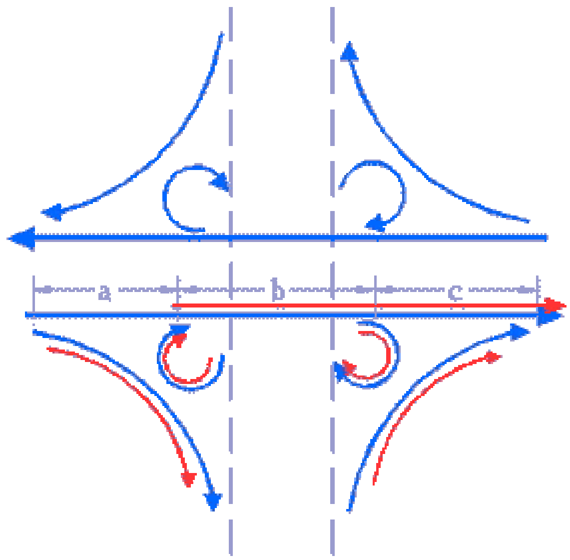

Figure 2. A Full Cloverleaf Interchange